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Ecologic Risk Assessment

INTRODUCTION

The ecologic risk assessment (ERA) for the Coeur d'Alene River basin (CH2M-Hill and URS Corp. 2001) was prepared under contract for the U.S. Environmental Protection Agency (EPA) Region X. The ERA is intended to support the remedial investigation/feasibility study (RI/FS) under the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA) regulatory framework. The purpose of an ERA under CERCLA is to describe the likelihood, nature, and severity of adverse effects to plants and animals resulting from exposure to hazardous substances. In the case of the Coeur d'Alene River basin, the hazardous substances in question represent historic and continuing releases of dissolved and particulate materials from mining operations that have been distributed from the upper and middle basin throughout the study area. The study area addressed in the ERA includes the Coeur d'Alene River and associated tributaries, Lake Coeur d'Alene, and the Spokane River downstream to the Spokane arm of Lake Roosevelt. Although performed under the direction of EPA, the ERA included stakeholder input through the Coeur d'Alene Basin Ecological Risk Assessment Work Group.

EPA used the results of the ERA as inputs to the RI/FS report and the record of decision (ROD) (EPA 2002) for the basin. The ERA addressed risks to plant and animal species exposed to contaminated surface water, sediment, and soil throughout the basin. For contaminated media that were found to pose significant risks, the ERA proposed preliminary remediation goals (PRGs)[1] for use in making remedial decisions at the site. Many of the actions included in the proposed remedy (as documented in the ROD) were specifically intended to reduce or eliminate risks to ecologic resources in the basin.

In the statement of task, the committee is directed to assess the adequacy and application of EPA's Superfund guidance in terms of currently available scientific and technical knowledge and best practices. Specifically, with regard to the Coeur d'Alene River basin site, the committee is to consider the scientific and technical aspects of the following:

- Assessing the ecologic risk from waste-site contaminants in the context of multiple stressors.
- The necessary data and appropriate analyses to estimate the ecologic risks attributable to waste-site contaminants—specifically, how well these analyses were applied to estimate the risks, including the effects of lead on migratory fowl.
- Whether risks attributable to sources other than mining and smelting activities were adequately analyzed.

In addressing the charge, this chapter reviews the Coeur d'Alene River basin ERA with respect to the following criteria:

- Consistency with agency guidance for ERAs
- Consistency with best scientific practice in ERA
- Validity of conclusions

In addition, the chapter addresses the extent to which the proposed remedy is consistent with the conclusions of the ERA and the likelihood that the selected remedy will significantly improve ecologic conditions in the Coeur d'Alene River basin.

In performing its review, the committee found it neither necessary nor appropriate to evaluate all of the underlying scientific studies or to identify all of the aspects of the ERA that could have been improved. The committee recognizes that at a site as large and as obviously disturbed as the Coeur d'Alene River basin, there is no limit to the number or types of data-collection activities that could have been conducted. Similarly, any ERA of the scope and complexity of the Coeur d'Alene River basin ERA could be

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[1]PRGs are proposed concentrations of materials in soil, sediment, and surface water below which adverse effects are expected to be absent or within defined limits. PRGs are provided to risk managers to assist in making decisions for remedial action (CH2M-Hill and URS Corp. 2001).

improved through better data analysis techniques and more thorough documentation. In reviewing this ERA, the committee chose to limit its review to the studies and analyses that were critical to supporting the conclusions and management recommendations.

CONSISTENCY OF THE ERA WITH EPA GUIDANCE CONCERNING THE ERA PROCESS

EPA's primary guidance on ERA can be found in the following documents: *Guidelines for Ecological Risk Assessment* (EPA 1998), *Ecological Risk Assessment Guidance for Superfund* (EPA 1997), and *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (EPA 1999). The Superfund program office has also developed secondary guidance on specific components of Superfund ERAs; all of these are available online. This section of the committee's report addresses whether or not EPA followed its own guidance in performing the ERA. The technical adequacy of the data and analyses used in the ERA are addressed below ("Evaluation of the ERA in the Coeur d'Alene River Basin").

Description of the ERA Process

It must be recognized at the outset that the ERA process followed by EPA is much less explicit than the human health risk assessment process. EPA's ERA guidance focuses primarily on the process used to design the assessment, evaluate the data, draw conclusions, and communicate the conclusions to risk managers. The overall process consists of the three steps depicted in Figure 7-1.

Problem Formulation

During problem formulation, the risk assessment team synthesizes information concerning the site being investigated, including the history of activities at the site, nature and spatial scale of the contamination, the types of habitats and organisms exposed, and the fate and effects of the chemicals identified at the site. Risk managers and stakeholders are consulted to identify ecologic management goals for the site. From the management goals and the types of organisms at risk, the risk assessors, risk managers, and stakeholders develop a set of "assessment end points," which define the specific types of organisms ("entities") and characteristics ("attributes") to be addressed in the ERA. An assessment end point for a risk assessment could be a specific fish or wildlife species (for example, bull trout or tundra swan) or a valued habitat type (for example, floodplain lake). Corresponding attributes could include mortality or growth in the case of a species or

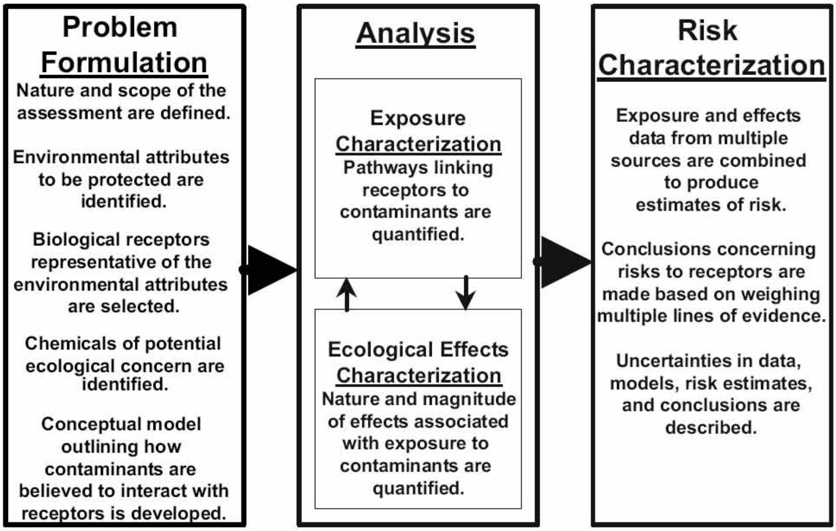

FIGURE 7-1 ERA process. SOURCE: CH2M-Hill and URS Corp. 2001.

plant community composition in the case of a habitat type. Once the assessment end points have been identified, the assessment team develops a conceptual model that shows the causal links between the hazardous substance releases and the assessment end points. A typical conceptual model would include the source of the hazardous substances that have been (or potentially could be) released, the fate and transport pathways through which the assessment end points are (or could be) exposed, and the adverse effects on those end points that are occurring (or could occur) as a result of the exposures. Once the assessment end points and conceptual model have been developed, the risk assessment team develops an analysis plan that identifies the specific types of data needed to complete the assessment and the methods that will be used to analyze the data and draw appropriate conclusions.

Analysis

During analysis, the risk assessment team implements the analysis plan developed during problem formulation. Depending on the circumstances, analysis may or may not include collection of new data. For chemical stressors, analysis typically is differentiated into separate "exposure" and "effects" components. In exposure analysis, a combination of field measurements and mathematical exposure models are used to estimate spatial and temporal patterns of exposure to the end point species and communities identified in problem formulation. In effects analysis, a combination of literature-derived toxicity information, toxicity tests performed on organisms present at the site, and field studies of the characteristics of exposed individuals, populations, and communities are used to estimate the ecologic effects of chemical exposures. Effects analysis can include development of exposure-response relationships for different types of effects and evaluation of evidence that particular types of adverse effects are caused by the stressor(s) being evaluated. EPA's guidance documents identify general categories of data and models that could be used in the analysis phase of an ERA, but do not specify which types of data or models should be used for different types of assessments. All such decisions are left to the assessment team, although the team's decisions ultimately are subject to review both inside and outside the agency.

Risk Characterization

In this process, the assessment team integrates the results of the exposure and effects analyses and draws conclusions about the magnitude and extent of risk to the end points of concern posed by the stressor(s) being evaluated. At least for chemical stressors, risk characterization includes both a quantitative and a qualitative step. In the quantitative step, termed "risk estimation," the assessment team develops numerical comparisons between exposure concentrations or doses and exposures expected to cause adverse effects. The comparisons are most often deterministic—for example, comparisons between mean or maximum exposure concentrations and single-valued toxicity benchmarks such as the lowest-observed-effect levels (LOELs). The comparison also can be probabilistic, where the exposure estimate, the effects estimate, or both are expressed as a probability distribution. Probabilistic methods are often used to estimate the fraction of an exposed population that may be exposed to a concentration or dose higher than a given toxicity benchmark. Probabilistic methods may also be used to develop risk curves that show probabilities of effects of differing magnitude.

If population- or community-level risks are being addressed, a mathematical model of population or community dynamics may be used to express the risk in terms of higher-level effects such as percent reduction in abundance, increased risk of extinction, and change in community composition. It should be noted that none of these techniques are specifically required by either the agency-wide guidelines or the Superfund guidance. The choice of which techniques will be used is left to the risk assessment team and the responsible project manager and is normally documented in a work plan prepared prior to the initiation of data collection.

The qualitative phase of risk characterization, which is termed "risk description" in the agency-wide guidelines, involves interpreting the magnitude, significance, and management implications of the quantitative risk estimates. Where multiple lines of evidence have been developed, risk description involves reconciling any inconsistencies between different types of evidence. In the case of Superfund ERAs, risk characterization also includes the development of PRGs intended to aid risk managers in designing an appropriate and effective remedy. PRGs are estimates of concentrations in environmental media that are expected to protect biota at the site from adverse effects of chemical exposure. The Superfund guidance recommends that both lower-bound and upper-bound values should be developed for each environmental medium of concern. The lower bound would be based on consistent conservative assumptions and no-observed-adverse-effects levels (NOAELs). Contaminant concentrations as low or lower than this lower bound should cause no adverse ecologic effects. The upper bound would be based on observed or predicted impacts and would be developed using less-conservative assumptions, site-specific data, lowest-observed-adverse-effects levels (LOAELs), or an impact evaluation. Contaminant concentrations as high or higher than the upper bound could cause adverse ecologic effects.

Evaluation of the ERA in the Coeur d'Alene River Basin

The following subsections evaluate EPA's ERA for the Coeur d'Alene River basin with respect to consistency with agency guidance.

Problem Formulation

Section 2 of the ERA, which documents the problem-formulation step, begins with a statement of management objectives and then derives assessment end points from those objectives and develops a conceptual model. The management objectives were developed with input from an ERA work group consisting of representatives of the states of Idaho and Washington; the Coeur d'Alene, Spokane, and Colville tribes; the U.S. Fish and Wildlife Service; and any other governmental or nongovernmental organizations that wished to participate.

Contaminants of potential ecologic concern (COPECs) were selected using a two-step procedure. In the first step, the available data on concentrations of chemicals in soil, sediment, and surface water were subjected to a data-quality review. Resultant values were then screened against soil/sediment background levels and ambient water-quality criteria (AWQC).

The assessment end points include individual species, biological communities, and physical habitat characteristics that could be adversely affected by mining-related hazardous substances. Taxonomic groups of organisms addressed included birds, mammals, fish, amphibians, and plants. Representative species belonging to each group were identified for each Conceptual Site Model (CSM)[2] unit and habitat type. The measures of mining-related effects selected for evaluation included reductions in survival, reproduction, growth, and abundance. For migratory birds and "special status" species (that is, threatened, endangered, or culturally significant species, or state or agency species of special concern) effects of mining-related hazardous substances on the health of individual organisms were also evaluated. For migratory birds and special status species, effects were considered to be adverse if any of the attributes of interest was observed or predicted to be adversely affected. For other species, effects were considered adverse only if a 20% or greater adverse change in an attribute of interest was observed or predicted. The use of a 20% effects level as a default de minimis criterion for ecologic significance was first proposed by Suter et al. (1995), on the grounds that this value is consistent both with EPA's regulatory practices and with the practical detection limits of typical toxicity testing protocols and field survey methods.

In addition to evaluating effects of mining-related hazardous substances on individual species, the ERA also evaluated effects on aquatic and terrestrial plant and invertebrate communities, soil processes, and physical/biological characteristics. Community-level effects addressed included effects on community composition, abundance, density, species diversity, and community structure. Physical/biological characteristics evaluated included habitat suitability indices, spatial distributions of healthy riparian communities, sediment deposition rates, and turbidity. Changes in these characteristics were addressed to account for secondary effects of hazardous substance releases (for example, degradation of riparian habitat resulting from toxic effects of hazardous substances on vegetation).

Section 2 concludes with lists of COPECs and receptor species to be evaluated. Separate lists of COPECs are provided for each medium, and separate lists of receptors are provided for each of six habitat types present in the basin.

The one component that is *not* included in the ERA is an analysis plan. Such a plan would normally be developed at the conclusion of the problem-formulation phase of an ERA. Data gaps identified during the development of the analysis plan would then be filled prior to implemen-

[2]The study area was divided into five CSM units in the ERA. These roughly correspond to the high-gradient watersheds in the upper (eastern) basin (CSM 1), the mid-gradient watersheds in the middle basin (CSM 2), the expansive depositional floodplain and lateral lakes area in the lower basin (CSM 3), Lake Coeur d'Alene (CSM 4), and the Spokane River (CSM 5); see Chapters 3 and 4 of this report for further discussion.

tation of the remaining steps in the ERA. The rationale for bypassing the analysis plan (CH2M-Hill and URS Corp. 2001, pp. 1-3 to 1-4) was that a large number of investigations had already been performed within the Coeur d'Alene River basin. These investigations included sampling of environmental media and biological tissues, bioavailability tests and toxicity tests to a wide variety of biota, and numerous biological surveys. As documented in Appendix A to the ERA, EPA used a series of workshops and meetings with stakeholders to identify additional data needs. It is possible that some of the methods used in the ERA may have been selected because they were consistent with existing data rather than because they were the best approach for quantifying risks to the assessment end points. Also, because the expansion of the Superfund site vastly increased the geographic extent of the site, ecologic effects in some areas may have been incompletely described.

Although in most respects the problem formulation step of the Coeur d'Alene River ERA appears to be consistent with the requirements of guidance, the failure to develop an analysis plan may have contributed to the continued existence of data gaps (discussed later in this chapter) that limit the value of the ERA results for guiding remedy design.

Analysis

Section 3 of the ERA, which documents the analysis phase of the risk assessment, provides information on the measures of exposure and effects used in the ERA.

For the exposure analysis, Section 3 identifies, for each CSM unit and habitat type, the routes by which each receptor could be exposed to the COPECs identified in the problem-formulation step. Data on COPEC concentrations in each medium serving as a source of exposure were summarized. For aquatic biota and soil invertebrates, the media concentrations provide direct estimates of exposure. Because wildlife receptors can be exposed to COPECs via direct and indirect pathways (ingestion of soil/sediment, water, and contaminated biota), the exposure assessment for these receptors used models to quantify multimedia exposures to COPECs. The data and models used are documented in Appendices A-D of the ERA.

The effects analysis utilized available data derived from published literature on the toxicity of individual COPECs to terrestrial and aquatic biota; tests of the toxicity of soil, sediment, and water collected in the Coeur d'Alene River basin; laboratory dosing studies performed to simulate waterfowl exposures to COPECs; and field studies performed in the basin. The toxicity data were used to define, for each receptor, a range of toxicity reference values (TRVs) for comparison with the estimated exposure concentrations or doses from the exposure analysis. Data sets and procedures used to develop these TRVs are documented in Appendices E and F of the ERA.

All the data and exposure models used in the analysis phase are identified in guidance as being appropriate for use in ERA; hence, Sections 3 and 4 of the ERA also appear to be consistent with available guidance.

Risk Characterization

The risk characterization section of the ERA (Section 4) synthesizes the exposure and effects analyses documented in Section 3. Both a risk estimation and a risk description component are included. In the risk estimation step, the exposure estimates for each receptor were compared with the TRVs documented in Section 3. For birds, mammals, and aquatic biota, point estimates of exposures were compared with point estimates of effects. For amphibians, terrestrial plants, soil invertebrates, and soil processes, full distributions of exposure and effects estimates were compared, with the risk represented by the percent overlap of the two distributions. Risk estimates derived from site-specific toxicity tests and field surveys were evaluated by comparison with reference conditions. All of the techniques used are identified in the agency-wide guidelines and in the Superfund guidance as being valid risk-estimation techniques.

The risk description evaluated all the lines of evidence for each receptor group. Greater weight was given to site-specific toxicity tests and field surveys than to risk estimates based on literature-derived toxicity data. Strength of risk conclusions was considered high if multiple lines of evidence, including site-specific field surveys and toxicity tests, were available for a given receptor and all lines of evidence were in agreement. Risk conclusions were considered to be of moderate strength if the data consisted of literature-based toxicity and one other line of evidence. If only literature-based toxicity data were available, the strength of risk conclusions was rated as low.

For each habitat, the risk characterization identified the receptors at risk and the COPECs posing the greatest potential risk to each receptor. The risk description section of the ERA also includes a qualitative evaluation of secondary effects of mining-derived hazardous substances on habitat quality. Uncertainties affecting all components of the risk assessment are summarized in a separate section on uncertainty analysis.

Risk calculations are documented in Appendices G-I of the ERA. These calculations appear to be consistent both with the formal requirements of guidance and with the procedures for risk characterization documented by Suter et al. (2000).

As discussed later in this chapter, the PRGs for aquatic organisms in sediment and water provided in the ERA are lower-bound thresholds as defined in the Superfund guidance. No upper-bound thresholds are provided in the ERA. In this respect, the risk characterization component of the ERA does not conform to the Superfund guidance. In all other respects, EPA's risk characterization is consistent with agency guidance.

CONSISTENCY OF THE ERA WITH BEST SCIENTIFIC PRACTICE

EPA guidance on ERAs focuses on procedures rather than on the quality or quantity of the data and models used. Therefore, beyond considering consistency with guidance, it is also necessary to evaluate, from a technical perspective, whether the assessment was properly designed and conducted and whether the conclusions are adequately supported. This section of the committee report evaluates the consistency of the ERA with best scientific practice in ERA. The question here is not whether EPA guidance was followed but whether the site-specific studies performed to support the assessment were properly designed and conducted and whether the supporting scientific literature was properly interpreted.

Problem Formulation

Range of Stressors Evaluated

All the stressors evaluated as COPECs are mining-related metals. Section 2.4 of the ERA report discusses the data and methods used to select COPECs for the ERA. The process involved examining all data available both from historical investigations and from sampling conducted specifically to support the RI/FS. These sources are summarized in Table 2-9 of the ERA report (CH2M-Hill and URS Corp. 2001). Media evaluated included soil, sediment, water, and biological tissues. Evaluation of the data included a data-quality review, data reduction, and association of sampling locations with CSM units and habitat types. Zinc is clearly the metal with the largest ongoing discharges in the Coeur d'Alene River basin, followed by lead and cadmium. Most zinc and cadmium are released and transported as dissolved metals. Most lead is present in particulate form and is transported with sediment, especially during flood events. As a result of historical flood events, particulate lead has been deposited in streambeds, lakes, riparian zones, and floodplains throughout the lower basin, Lake Coeur d'Alene, and the Spokane River. Based on the environmental concentration data and comparisons to screening levels, as described above, the selection of COPECs was reasonable.

Non-mining-related stressors were not explicitly considered in the ERA. These types of stressors include habitat modification, infrastructure development (roads and railways), and stream channelization. Mining-related stressors besides metals, particularly sediments associated with mining and milling activities that were released to streams in vast quantities, also were not explicitly addressed in the ERA. As stated in the ERA (CH2M-Hill and URS Corp. 2001, p. 2-39),

> The EcoRA [ecologic risk assessment] does not attempt to quantify the relative effects of mining activities and other stressors. As part of the natural resource damage assessment (NRDA) process, a determination and initial quantification of mining-related injury to natural resources has been completed.

Some mention is made of the potential effects from non-mining-related stressors. Figure 2-16 in the ERA illustrates how non-mining-related stressors could affect the receptors evaluated in this ERA and identifies resource management, fire, waterborne log transport, watershed management, roads and railroads, hydraulic modification, housing and urban development, and septic/waste disposal systems as potential non-mining-related stressors. Appendix K of the ERA, which evaluates the secondary effects of mining-related hazardous substances (for example, loss of riparian habitat and stream bank stability), concludes that non-mining-related stressors (development, road building) also contribute to these secondary effects, but the relative contribution of mining-related hazardous substances (presumably metals) and other stressors cannot be quantified. According to the ERA (CH2M-Hill and URS Corp. 2001, p. 2-40), physical disturbances unrelated to mining were accounted for in the ERA by comparing site-specific information on biota and habitats from mining-affected areas with information on biota and habitats from non-mining-affected reference areas believed to be affected by the same types of non-mining-related disturbances.

The consideration of areas with similar levels of infrastructure as a reference is appropriate, especially in light of the preponderance of evidence relating to the ecologic effects of metals in the Coeur d'Alene River basin environments. Because the purpose of ERAs performed at Superfund sites is to evaluate risks associated with releases of hazardous substances, the focus on metals as stressors is reasonable. Impacts of physical disturbances, including non-mining-related disturbances, would still have to be considered during remedy selection and implementation, but they need not be explicitly addressed during the risk assessment component of the RI/FS process.

Characterization of Existing Ecologic Conditions

The Coeur d'Alene River basin is a complex ecologic zone consisting of the Coeur d'Alene River and tributaries, lateral lakes, Lake Coeur d'Alene, and the Spokane River. The question is, was a reasonable survey conducted to identify the aquatic and wildlife resources in these various habitat zones for evaluation, and was this reported in the ERA?

Section 2 of the ERA lists the groups of receptors of concern within each CSM unit and habitat type within the basin, summarizes linkages between these receptors and habitat characteristics that could indirectly be affected by hazardous substance releases, and lists representative plant and animal species and community types found within each CSM unit and habitat types.

As documented in Section 2.3 of the ERA, ecologic conditions within the upper basin were characterized based on the many ecologic investigations conducted since the 1980s. Many of these studies were performed to support a Natural Resource Damage Assessment for the Coeur d'Alene River basin (Stratus 2000). In the lower basin, extensive surveys (Audet et al. 1999) have been conducted to document waterfowl mortality. These studies, in combination with necropsy findings, have characterized the acutely toxic effect of metals-contaminated sediments on waterfowl. Far less information about the aquatic communities in the lower basin is available. As stated in the ERA (CH2M-Hill and URS Corp. 2001, p. 2-24), "Fish population assessments conducted in the main stem confirm the presence of numerous fish species. However, the information gathered is too limited to use to draw conclusions about the current status of fish populations." For macroinvertebrate communities, the ERA concludes "the current status of the macroinvertebrate community [in the main stem of the river] cannot be determined at this time." The limited data on the status of these communities preclude a complete assessment of the impact of metals from mining-derived sources. A similar situation exists for aquatic communities in Lake Coeur d'Alene. This recognition is not new; in a 1988 report (Hornig et al. 1988), EPA recommends that

> Future assessment should further document status and condition of populations, particularly of those fish that inhabit the mainstem Coeur d'Alene and lateral lakes and the salmonids that use the Coeur d'Alene River for migration to spawning areas upstream of the South Fork confluence.

The ERA could not evaluate ecologic risk to every organism within the Coeur d'Alene River basin. Receptors of high ecologic or societal value, or those that were believed to be representative of broader groups of organisms, were selected for evaluation. The receptors for the exposure analysis were chosen to represent a trophic category and particularly feeding behaviors, such as various bird feeding behaviors, that would represent different modes of exposure to the chemicals of potential concern—in particular lead—for wildlife. The following criteria from the ERA were used to select potential receptors (EPA 2002, p. 7-21):

1. The receptor utilized habitats present in the basin.
2. The receptor is considered important to the structure or function of the ecosystem of the Coeur d'Alene River basin.
3. The receptor is statutorily protected, in particular those that are identified as threatened or endangered species or migratory birds that have a higher level of statutory protection.
4. The receptor is reflective and representative of the assessment end points for the Coeur d'Alene River basin.
5. The receptor is known to be either sensitive or highly exposed to the toxic metals in the Coeur d'Alene River basin.

Section 2.3 of the ERA also identifies federally listed and state-listed or candidate species potentially present within the study area. This section also summarizes previous studies of biological conditions and metal contamination throughout the basin. This information appears to be adequate to identify representative species and communities for use in the risk assessment, although not sufficient to fully characterize risks to all of these receptors.

Management Goals, Assessment/Measurement End Points, and Conceptual Model

EPA consulted with other agencies and stakeholders in development of the following two management goals for the site:

- Maintenance (or provision) of soil, sediment, water-quality, food-source, and habitat conditions capable of supporting a "functional ecosystem" for the aquatic and terrestrial plant and animal populations in the Coeur d'Alene River basin.
- Maintenance (or provision) of soil, sediment, water-quality, food-source, and habitat conditions supportive of individuals of special status biota (including plants and animals) and migratory birds (species protected under the Migratory Bird Treaty Act) that are likely to be found in the Coeur d'Alene River basin.

The risk assessment team then developed assessment end points at the individual, population, community, and habitat/ecosystem/landscape levels intended to support these goals.

Individual-level end points included migratory bird species and threatened or endangered species covered under the second of the above goals. These types of species are protected by statute (the Migratory Bird Treaty Act and the Endangered Species Act), and detrimental effects on the health, survival, growth, or reproduction of any individual belonging to such species are considered adverse. The remaining assessment end points relate to the first goal. Population-level assessment end points included various species of birds, mammals, fish, amphibians, and plants. For these species, effects were considered adverse if key population attributes such as reproduction, survival, growth, or abundance were to be reduced by 20% or more or if greater than 20% of the individuals present in a population could be affected. Community-level end points included aquatic and terrestrial plant communities and aquatic and terrestrial invertebrate communities. For these end points, individual species were not identified. Effects were considered adverse if there was greater than a 20% reduction in key community-level attributes. Habitat/ecosystem/landscape-level end points included soil process and physical and biological landscape attributes. Effects on soil processes were considered adverse if measures of soil microbial function or other measurable soil processes were reduced by 20% or more. Effects on physical and biological characteristics were considered adverse if any measurable level of degradation of habitat structure occurred.

Specific measures of exposure defined for the site included concentrations of chemicals in sediment, soil, surface water, and biota. The types of assessment end points found in each CSM unit and habitat type were summarized (CH2M-Hill and URS Corp. 2001, Table 2-1), and a variety of specific attributes that could be adversely affected by chemical exposures were identified for each assessment end point. Indirect effects of chemicals that occur as secondary effects of alterations in physical and biological ecosystem characteristics were discussed.

A conceptual model was developed (CH2M-Hill and URS Corp. 2001, Figures 2-15 to 2-21) showing, for each CSM unit, the linkages between sources and assessment end points. Both chemical and physical effects of mining are included in these figures.

It could be argued that the extensive list of assessment end points developed for this ERA is excessively complex, given the obvious and well-documented impairment of aquatic and terrestrial biota throughout the basin. However, these end points are clearly related to the management goals and appear to be sufficient to support the subsequent analysis of ecologic exposures and effects.

Analysis

The analysis phase of an ERA includes consideration of all relevant aspects of the environmental transport, fate, and effects of a hazardous substance release, as identified in the problem-formulation section of the risk assessment. The analysis is conceptually separated into an "exposure" assessment and an "effects" assessment, although these two assessment components are necessarily closely linked. This section of the report addresses the technical adequacy of the exposure and effects analyses documented in the ERA.

Exposure Analysis

This section addresses the adequacy of the exposure assessment component of the ERA. Questions to be addressed include whether all the significant exposure pathways were identified, whether physical transport processes and environmental transformations were adequately characterized, and whether seasonal and spatial variability were adequately addressed.

Environmental Transport

The ERA was developed in tandem with the RI (URS Greiner, Inc. and CH2M Hill 2001a), and, as stated in the ERA, "some information briefly presented in the [ERA] will be presented in greater detail in the RI/FS" (CH2M-Hill and URS Corp. 2001, p. 1-1). In this case, the RI describes the magnitude and location of metals contamination in the basin and presents information about their disposition (see Chapter 4 of this report for evaluation of the RI). Extensive previous studies over a period of several decades and those conducted in support of the RI inform the characterization of contaminants and their transport through the basin. A database of metals concentrations in surface water was compiled for the RI from which expected values for metals loading through the basin were determined.[3] Metals loading diagrams are presented in the ERA and demonstrate that the original Bunker Hill Superfund site (the box) is the portion of the system contributing the largest loads of dissolved zinc, followed by Canyon and Ninemile Creeks. In contrast, the largest contributor of total lead is the broad depositional valley downstream of Cataldo.

Although this information provides a concise summary of expected loading, it is less useful for understanding the frequency, intensity, and duration of episodic extreme events (for example, flooding that mobilizes large amounts of lead-contaminated sediments or prolonged low-flow conditions containing high concentrations of dissolved metals). These events likely contribute significantly to potential toxic effects in ecologic systems in the basin. For example, Audet et al. (1999) described the impacts of severe flooding events on waterfowl:

[3]The database of environmental metals concentrations used to provide expected loading values in the RI is not the same database used to estimate exposure point concentrations in the ERA (although similar information is presented in both databases). The committee did not seek to evaluate the differences in these two data sets, except as noted below in the section "Dose Quantification."

> Large die-offs (>100 dead birds reported) occurred in 1953, 1954, 1982, 1996, and 1997. Some of these years were associated with high water events followed by low water conditions allowing for newly deposited sediments to be more readily available in waterfowl feeding areas. Beckwith (1996) reported the February 1996 flood event as the second largest flood event recorded in the Coeur d'Alene River basin based on gauge data collected from 1911 to present.

Environmental Chemistry

Speciation is a fundamental aspect of metal risk assessment for both aquatic and terrestrial systems. It is widely recognized that mobility, bioavailability, and toxicity can vary dramatically as a function of metal species. As a consequence, exposure and risks may be over- or underestimated if chemical speciation is not considered. In the Coeur d'Alene River basin, the metals arise from primary sources (such as tailings) or secondary sources (such as metals that have been redeposited) as a result of biotic or abiotic processes. In mine tailings, the zinc and lead, which are of primary concern, are largely present as sulfides. Sulfide minerals have low mobility, but mobility is greatly enhanced through oxidation of the sulfides to form secondary mineral species with much higher solubility. Changes in chemical form likely occur as metal-containing particles are eroded from tailings particles, deposited in the riverbed, and then are repeatedly resuspended and redeposited in the river channel and floodplain.

Bioavailability is discussed in Section 3.1 of the ERA, but the ERA did not address variations in bioavailability related to metal speciation.[4] For example, lead bioavailability to birds was assumed to be 50%, based on a feeding study conducted by Hoffman et al. (2000) in which contaminated wetland sediments were fed to mallard ducklings. However, the sediments used in the feeding trials, which likely would have been anoxic in situ, were dried and consequently subjected to oxidation before being used in the tests. Upon aeration, much of the sulfide and iron in the sediment would have oxidized and the lead released from its sulfidic form would have sorbed to the newly formed iron oxide. This change in speciation would have substantially enhanced the bioavailability of the lead, and therefore the bioavailability factor developed from this study would have overestimated the bioavailability of the sulfidic lead present in undisturbed wetland sediment. Overestimation of bioavailability in turn would lead to an excessively conservative estimate

[4]In fact, EPA provided to the committee that "We note that, because of the site-specific information on bioavailability (Hoffman et al. 2000 for ecologic receptors and the large body of paired blood lead and environmental data for children that was developed as part of the Bunker Hill Box residential areas cleanup), understanding speciation was not necessary to evaluate health risks" (EPA 2004).

of the remediation goal required to protect waterfowl from lead ingestion. The degree of overestimation would depend in part on the relative consumption of anoxic vs. oxidized sediment by waterfowl.

Dose Quantification

In general, EPA's exposure assessment adequately addressed exposures to aquatic biota; however, the committee still has questions about the procedures EPA used to select the data used in the ERA. Multiple studies have been conducted to document metals contamination in the Coeur d'Alene River basin and have resulted in a large database of metals concentrations in various media at various locations over time. This database from numerous sets of historical data collected by EPA, the U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service, Bureau of Land Management, University of Idaho, and other investigators underwent "data qualification review and reduction protocols," described in the ERA (CH2M-Hill and URS Corp. 2001, Section 2 and Appendix A). This process essentially winnowed down a larger database into a smaller one used within the ERA and from which summary statistics for each habitat within each CSM unit could be determined. The committee could not conduct a case-by-case review of this process and the database and resulting statistics; however, it was determined that the data-reduction technique eliminated chemical data for surface water in the main body of Lake Coeur d'Alene.[5] The end product of the data-qualification process is important as these data are used in the ERA to determine risk on the basis of water concentrations of the metals (CH2M-Hill and URS Corp. 2001, p. 4-21), and it is this risk that is considered in the weight-of-evidence analysis in risk characterization (see below). As a result, this line of evidence was not available for consideration on Lake Coeur d'Alene.

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[5]Table A5-4 of the ERA (CH2M-Hill and URS Corp. 2001, Appendix A) presents summary statistics for the data retained for further analysis in the ERA. Data on surface-water zinc concentrations for segment 2 (the main body of the lake) are not presented, whereas segments 1 and 3 of Lake Coeur d'Alene (representing the St. Joe River arm and Wolf Lodge Creek arm of the lake, respectively) are presented in the summary table (see CH2M-Hill and URS Corp. 2001, Figure 2-13 for a map). The arithmetic mean dissolved zinc levels in these segments are 9.93 μg/L (segment 1) and 8.07 μg/L (segment 3). Apparently, many of the data for these segments are not from the lake. For instance, data for the St. Joe segment (segment 1) are at least partially derived from the USGS sampling station in Calder, approximately 30 miles upriver from Lake Coeur d'Alene, and St. Maries, Idaho, approximately 8 miles upriver from Lake Coeur d'Alene. Data for the main body of the lake are not presented, although the lake has been the subject of numerous water-quality studies. For example, dissolved zinc data from 1999 collected by USGS are available online (USGS 2005). In contrast to the ERA, the RI does present concentration data for dissolved zinc for segment 2 of the lake (average = 174 μg/L for segment 2 [URS Greiner, Inc. and CH2M Hill 2001b, attachment 3]).

Information on exposures to fish and benthic invertebrates in Lake Coeur d'Alene is very limited, especially regarding sediment effects to benthic fauna and the bioavailability of sediment-bound metals. Although sediment metals and metal concentrations in the overlying water have been sampled, there is a paucity of data on the dynamic interaction between invertebrates, the deposited sediments, and the potential for re-entrainment into the water column. This remains a clear need for further investigation, as any management program must understand the ramifications of potential changes in the abundance and functional activity of the lake benthos.

The primary metal exposure routes for fish and benthic invertebrates in the Coeur d'Alene River and tributaries are through aqueous exposure over the gills or through dietary (food chain) uptake (see Box 7-1). The exposure

BOX 7-1 Metals in the Food Chain and Diet of Trout in the Coeur d'Alene River

In addition to exposures to metals from water, trout can also be exposed through consumption of organisms or material that has elevated metal content. In the Coeur d'Alene River system, these types of dietary exposures have been characterized.

Farag et al. (1998) observed an accumulation of metals in biofilm (algae, bacteria, and detritus attached to the substrate), invertebrates, and whole fish in mining-affected portions of the South Fork of the Coeur d'Alene River compared with reference sites. This study demonstrated that concentrations accumulated to the highest levels in biofilm and sediments, followed by invertebrates and fish, indicating that constituents of the aquatic food chain contain elevated metals concentrations, which can be passed on to trout. Mean lead concentrations were highest in samples collected from the Ninemile and Canyon Creek sediments with biofilm lead > 25,000 μg/g and 12,000 μg/g, respectively. Mean lead concentrations in whole perch collected in the lower basin were much lower than those measured in sediments, biofilm, or invertebrates; however, body burdens of lead were measured at greater than 50 μg/g. Burdens of cadmium, lead, and zinc were also elevated in trout kidney and gill compared with the reference streams.

Woodward et al. (1999) compared biota from sections of the South Fork with reference sites in the St. Regis River that were morphologically similar. They determined that "there was a significantly higher concentration of cadmium, copper, lead and zinc in the food web (water, sediment, biofilm, and benthic invertebrates) of the South Fork over that of the St. Regis River and higher concentrations in the food web components were also reflected in significant exposure of trout gill, liver, and intestine."

Farag et al. (1999) demonstrated that cutthroat trout fed metals-contaminated benthic invertebrates from the main stem and South Fork of the Coeur d'Alene River accumulated significantly greater body burdens of zinc compared with those fed a diet from the North Fork (used as a reference). The study indicated negative biochemical, histologic, and behavioral effects, and decreased growth as a result of metals in the diet. The researchers emphasize the importance of these exposures to young fish whose diet consists primarily of benthic invertebrates.

is chronic, as groundwater and surface sources continually add cadmium, lead, zinc, and other metals to the river. Exposure point concentrations in the ERA for surface water are dissolved metal concentrations, whereas exposure point concentrations for sediment are reported as total metals in sediment. Substantial databases of concentrations in these media exist for waters in the basin. Concentrations of metals in fish liver and kidney, representing "internal exposures" are also presented. A mathematical relationship was developed between sediment concentrations and concentrations in fish tissue (kidneys in rainbow, cutthroat, and brook trout) and was used to estimate metal concentrations in kidneys of trout throughout the basin. The analysis relies on data that are likely too limited to extrapolate basinwide (twenty trout total from one reference and two affected locations) and statistical issues limit the use of the regression model (for example, using individual data points [sediment concentrations] in a regression of arithmetic means to provide distributions of concentrations in individual fish), although, ultimately, it does not appear that the results of this analysis had substantial bearing on the weight-of-evidence approach used in the risk characterization.

External exposures for birds and mammals evaluated in the ERA are primarily through contact with contaminated soils and sediments. Extensive studies characterizing the concentrations in these media existed for use in the ERA, particularly for habitats in the lower basin. Where data on COPEC concentrations in tissues were available, EPA also evaluated potential effects of these internal exposures. Considerable effort was expended to develop exposure models that incorporated the feeding ecology of swans, with their potential exposure to sediment-based lead. In addition to the extensive data sets available for waterfowl, more limited surveys provided data on concentrations of cadmium and lead in livers and concentrations of lead in blood were available for minks, muskrats, deer mice, voles, and horses.

Direct quantification of relationships between soil/sediment lead concentrations and resulting doses was possible for some wildlife species; however, for most mammalian and avian wildlife receptors, doses were estimated with mathematical models similar to those used to quantify human exposures to contaminated environmental media. Wildlife can be exposed to chemicals through three routes: dermal absorption, inhalation, and ingestion. Data for estimating dermal absorption or inhalation exposures generally are not available for wildlife; therefore, ingestion was the only pathway considered in exposure modeling.

The model used to quantify doses received through ingestion considered three sources of exposure: soil/sediment, food, and water. For soil/sediment and water, doses were estimated by multiplying the concentrations of each chemical in the appropriate medium by a species-specific ingestion rate (obtained from published literature or site-specific studies) and a chemical-specific gastrointestinal absorption rate. Values for metals other than lead were derived from published studies of metal bioavailability in mammals. For lead, absorption rates were estimated from site-specific data.

Doses received from metal-contaminated food were quantified with bioaccumulation models. These models estimate the dose received from each food type consumed by a given receptor as a function of the concentration of a chemical in that food type multiplied by the consumption rate of that food type. Concentrations of metals in food organisms were estimated through a combination of site-specific data and literature-derived bioconcentration factors. The bioconcentration factors relate concentrations of metals in soil/sediment or water to concentrations in the tissues of exposed biota. Total doses of each metal were obtained by summing the contribution of each food type.

To apply the models, concentrations of metals in sediment/soil and water for all samples collected within a given CSM unit and habitat type were used to generate summary statistics. Within CSM unit 1, the data were further subdivided by watershed. The upper 95% confidence limit on the arithmetic mean concentration in each medium was used as the exposure point concentration for dose quantification. The models described above were then used to convert concentrations of metals in soil/sediment to doses received by mammalian and avian receptor species. Doses were estimated by multiplying the exposure point concentration in sediment by the species-specific sediment ingestion rate and the site-specific gastrointestinal absorption factor.

A site-specific waterfowl model was developed by using site-specific information and an adaptation of the exposure/effects model presented by Beyer et al. (2000). This model was used to generate estimates of concentrations of lead in blood and liver from incidental ingestion of sediment for tundra swans, Canada geese, mallards, and wood ducks. Previous research specific to the Coeur d'Alene River basin has indicated that exposure of waterfowl to lead is trivial in the food pathway compared with sediment ingestion (Beyer et al. 2000). Therefore, dietary exposure is assumed to be represented by sediment exposure, which is reasonable. Diet-to-blood and diet-to-liver bioaccumulation models were developed with data from studies in which waterfowl were fed diets containing sediments from the Coeur d'Alene River basin (for example, Heinz et al. 1999). Sediment-to-tissue bioaccumulation models were also developed for American dipper (cadmium, copper, mercury, lead, and zinc in liver) and for small mammals (cadmium, lead, and zinc in liver and kidney). These models were parameterized using literature-derived rather than site-specific data.

For the mammalian and avian receptor species for which deterministic exposure modeling predicted the highest risks, probabilistic exposure analysis was performed using Monte Carlo methods. The probabilistic exposure models represented the various exposure parameters as statistical distributions rather than point estimates and expressed the resulting doses as statistical distributions.

All the modeling methods used in the ERA are well-documented in the scientific literature. The parameter values that were used are fully documented in Appendices C and D to the ERA. The documentation of these values is thorough and comprehensive, and reasonable decisions appear to have been made about the use of literature-derived data when site-specific data were unavailable. However, site-specific data for validating the exposure estimates are available only for waterfowl exposures to lead. Exposure estimates for all other wildlife receptors are substantially more limited and uncertain. Even the exposure estimates for waterfowl are somewhat uncertain because of the lead-speciation concerns discussed earlier.

Effects Analysis

Various types of data can be included in an ecologic effects analysis. For the Coeur d'Alene River basin ERA, EPA evaluated data from literature-derived single-chemical toxicity tests, site-specific toxicity tests, and field surveys. Some studies were used to derive TRVs and PRGs; others were used as supporting evidence concerning the presence and magnitudes of risks. This section evaluates the technical adequacy of the effects assessment included in the ERA. Questions addressed include whether the underlying studies conform to best scientific practices, whether all the available and relevant data were considered, and whether the data were properly interpreted.

Aquatic Receptors

Metals have long been understood to be toxicants and substantial data exist in the literature on the effects of metal exposures on aquatic organisms. The ERA collected data on metal effects (adjusted for water hardness) on aquatic receptors from the national database (AQUIRE)—a database with results of aquatic toxicity tests. Site-specific tests (using Coeur d'Alene River water or sediments) on aquatic organisms were also assessed and described in the ERA, including laboratory-based lethality tests with salmonids and invertebrates and sublethal behavioral tests. In situ assays ("live box" tests) conducted with fish placed in the environment to monitor mortality are also summarized in the ERA. Surveys of populations in the field were also reviewed to document effects and to evaluate populations of benthic macroinvertebrates, trout, and sculpin.

In the Coeur d'Alene River, metals of concern for fish and benthic invertebrates include zinc, cadmium, and, to a lesser extent, lead. The ERA indicates the sensitivity of the salmonids and other aquatic organisms in a series of plots derived from the literature describing the acute and chronic toxicity of metals to aquatic organisms (CH2M-Hill and URS Corp. 2001, Figures 3-23 to 3-30). There are numerous reports of the sensitivity of trout in the Coeur d'Alene River to dissolved metals. Toxicity tests conducted for the state of Idaho indicated that, of organisms tested in a battery of bioassays conducted on field-collected fish and invertebrates (EVS 1996a), westslope cutthroat trout were the most sensitive of resident species. However, they are less sensitive to metals than hatchery-reared fish. Other tests by the same firm (EVS 1996b) determined that water samples from South Fork Coeur d'Alene River near Wallace downstream of Canyon Creek were acutely toxic to hatchery-reared rainbow trout, whereas South Fork River water collected at stations upstream from Wallace (near Mullan and near the river's headwaters) did not have a toxic effect. In a series of studies on trout sensitivities to metals in Coeur d'Alene and Clark Fork Montana River waters, Woodward and colleagues (1997, 1995) have measured the great sensitivity of trout to metals (copper, zinc, cadmium, and lead). Trout spent as little as 3% of the time in contaminated water when given a choice of movement, and the fish avoided zinc concentrations as low as 28 μg/L. Farag et al. (1998) demonstrated that trout and other biota in the Coeur d'Alene system contain elevated concentrations of metals and, in another study, that the growth and survival of cutthroat trout were reduced when they were fed macroinvertebrates from the South Fork (Farag et al. 1999). Live-box tests conducted and described by Hornig et al. (1988) along with more recent tests (for example, Woodward 1995 and Woodward et al. 1999) demonstrated the acute toxicity of water from the South Fork and main stem of the Coeur d'Alene River to unacclimated hatchery-reared trout.[6]

Field surveys for fish were conducted to support the Natural Resources Damage Assessment (Stratus 2000) and are described in the ERA. These surveys found an absence of fish in some segments of Canyon Creek and Ninemile Creek and reduced populations in the South Fork compared with

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[6]These results could appear to conflict with the verbal accounts and population surveys that indicate the presence of trout in the main stem and south fork of the river. The presence of fish in these waters is not surprising though, as fish can become acclimated to elevated levels of soluble metals through biochemical changes such as metallothionein (a metal-binding protein) production and behavioral responses such as periodic movement into less contaminated areas. Resident fish can acclimate to elevated metals concentrations (or may simply be migrating through an area). As a result, it is expected that some fish could be caught in population surveys or recreational outings.

reference areas along the St. Regis River. However, upstream from Wallace—an area still affected by mining but with lower metals concentrations—the abundance and age distributions of trout populations were found to be similar to those in reference locations (CH2M-Hill and URS Corp. 2001, p. E-59). A more recent study (Maret and MacCoy 2002) corroborates these surveys but indicates the absence of sculpin from metals-affected reaches of the rivers where they otherwise would be expected to be found. Sculpin abundance and age class were found to be more sensitive than salmonid population characteristics as indicators of metal-related stress.

The approach used in the ERA, to address risks to fish in the upper and middle Coeur d'Alene River, was robust and based on a large number of high-quality laboratory and field studies. The results appear to have been properly interpreted.

Relatively limited information was available for assessing risks to benthic macroinvertebrates in the Coeur d'Alene River. Site-specific toxicity tests were performed using benthic invertebrates collected from the South Fork, but these tests addressed only the toxicity of the contaminated water and not the underlying sediment. Data were available from three independent surveys of benthic macroinvertebrate communities within the basin, but the studies used different sampling methods and could not be easily compared. Given the obvious impacts of mining-related hazardous substances on fish communities in the upper and middle Coeur d'Alene River basin, the committee believes that the existing data are sufficient to show that benthic invertebrates in the upper and middle basin are probably also at risk from exposure to mining-derived metals. However, an integrated laboratory and field study designed specifically to support the ERA could have provided a much stronger foundation for the PRGs developed in Section 5 of the ERA.

The available data for fish and invertebrates in the lower basin are substantially more limited than for the upper basin and do not appear sufficient to support any meaningful conclusions about the existence and magnitude of risks. To address risks present in Lake Coeur d'Alene, the ERA relies largely on one study by Ruud (1996), in which a qualitative survey was conducted for benthic invertebrates in the lake. No metals data were collected; hence, as the ERA states, "no definitive conclusions can be drawn from this work regarding the potential impact of metal concentrations in the lake on benthic macroinvertebrates."

Terrestrial Receptors

Although terrestrial plants and animals in the Coeur d'Alene River basin are exposed to a large number of mining-related hazardous substances, almost all of the animal studies performed within the basin have focused on lead. The adverse effects of lead in wildlife range from biochemical changes (for example, inhibition of the δ-aminolevulinic acid dehydratase enzyme involved in blood formation) to death. Waterfowl are particularly sensitive to metals-contaminated sediments that are ingested during feeding. Waterfowl are emphasized in this section and elsewhere because of the strong focus on waterfowl in the ERA and in the committee's statement of task.

The ERA considered a variety of studies from the literature on effects to terrestrial receptors to determine TRVs. A variety of site-specific laboratory studies have been conducted on waterfowl exposed to Coeur d'Alene River sediments in their diet to observe changes in biochemical parameters, growth, and other manifestations of lead toxicity. Target organ effects concentration data were derived from both site-specific observations and studies from the literature. The site-specific studies considered are described in Appendix E of the ERA. In general, a variety of biochemical and histological changes were seen in waterfowl exposed to contaminated sediments, especially when the sediments were combined with a nutritionally suboptimal diet.

Exposure of waterfowl to lead typically occurs in the wetland habitats used as feeding areas in the lower Coeur d'Alene River basin. These areas exhibit high concentrations of lead, often exceeding 4,000 milligrams per kilograms (mg/kg) (Campbell et al. 1999). Bookstrom et al. (2001, p. 18) estimated that 72% of the lower basin floodplain sediments had lead concentrations greater than 1,000 mg/kg. The ROD (EPA 2002) states that 95% of the wetland habitats in the lower basin have lead concentrations greater than 530 mg/kg. Waterfowl mortality events have been described in the lower Coeur d'Alene River basin for decades (Chupp and Dalke 1964; Audet et al. 1999); observations extending back to 1924 document exposure to and deaths from toxic materials. These mortality events tend to be greatest after winter flood events, and important routes of exposure are believed to be through ingestion of newly deposited sediments on vegetation or through consumption as grit (Audet et al. 1999).

Particularly compelling are the results from the recent field surveys combined with laboratory necropsy findings. The ERA describes a number of studies in which blood and tissues from sick and dead waterfowl collected in the lower basin were analyzed. These birds demonstrated high lead concentrations and histological indications of lead toxicosis compared with reference areas, yet had no indications of the presence of man-made lead artifacts such as lead shot or sinkers. For tundra swans (a species particularly sensitive to lead toxicosis) the ERA documents high lead concentrations in the liver that, for those animals found dead in the basin and diagnosed with lead poisoning, are consistent with levels in the literature indicative of lead toxicosis (Honda et al. 1990; Pain 1996).

Audet et al. (1999) documented animals found dead or sick in the Coeur d'Alene and St. Joe River basins between 1992 and 1997; of 682 animals found dead in the Coeur d'Alene River basin, 289 were tundra swans, 178 were Canada geese, and 55 were mallards. Lead poisoning was diagnosed in 80% of the 311 animals submitted for necropsy. Of the 250 lead-poisoned animals (elevated lead levels in the liver and histopathology indicative of lead toxicosis), approximately 92% did not have man-made lead artifacts (fishing sinkers, lead shot). This study also demonstrated a significant relationship between the sediment concentration of a feeding area and the presence of poisoned swans.

From the information presented on effects, it is apparent that wildlife are exposed to lead in the Coeur d'Alene River ecosystem. In particular, tundra swans are highly exposed and obviously quite sensitive to lead intoxication, which results in substantial poisoning and subsequent mortality. Multiple species of wildlife, in particular birds, ingest contaminated sediment, resulting in high levels of lead in their tissues. A variety of studies presented in the ERA document adverse biochemical and physiologic effects to Coeur d'Alene wildlife as well as mortality. The overall conclusion that lead exposure exceeded toxicity thresholds is supported by measurements of lead residues in blood and other tissues and by laboratory work and confirming field work. Further, lead exposure and effects were spatially consistent, in that areas with very high sediment concentrations and waterfowl utilization were also the areas with the highest observed waterfowl mortality.

Two site-specific toxicity studies on mammals have been conducted in the basin. One of these was a feeding trial on horses using grass hay grown in the area of the ore smelter (summarized in Appendix E of the ERA). This study was used to develop a lead TRV for large mammals. The other was a study of lead uptake from soil performed using volunteer human subjects. This study was used to develop a dietary absorption factor for estimating dietary uptake of lead by large mammals.

Both site-specific toxicity tests and field survey results for amphibians are summarized in Appendix E of the ERA. EPA judged the toxicity tests to be of limited value because of lack of information concerning sample locations and metal concentrations in the sediment used in the tests. A field study found decreased hatching success and overall survival as a function of increasing metal concentrations in sediment. This study was used to derive site-specific dose-response relationships for cadmium, lead, and zinc. Another field study compared amphibian communities at various sites within the basin to communities found in reference areas.

For plants, site-specific tests evaluating the phytotoxicity of metals present in site-related soils (summarized in Appendix E of the ERA) were performed using standard agricultural test plant species (alfalfa, wheat, and lettuce). These studies demonstrated negative relationships between soil metal concentrations and plant growth. In addition, a field study of plant community composition in contaminated and uncontaminated areas was performed. This study (also summarized in Appendix E) showed that a wide variety of measures of plant community composition were reduced in heavily contaminated areas.

To supplement the site-specific studies and to permit assessment of risks to a wider variety of receptor species than those for which site-specific data were available, the ERA relied on literature-derived TRVs. These TRVs are necessarily highly uncertain as applied to wildlife within the Coeur d'Alene basin.

Risk Characterization

As noted previously, EPA's approach to risk characterization involved development and evaluation of multiple lines of evidence regarding risks to each receptor group.

For birds, the following four lines of evidence were used, although not all lines of evidence were available for all species:

1. Comparisons of modeled dietary doses with literature-derived toxicity benchmarks
2. Comparisons of measured or modeled concentrations of COPECs in blood, liver, and kidney with tissue-specific toxicity benchmarks
3. Site-specific toxicity tests
4. Site-specific field surveys

For mammals, the following three lines of evidence were used:

1. Comparisons of modeled dietary doses with literature-derived toxicity benchmarks
2. Comparisons of measured concentrations of COPECs in liver or kidney tissue with tissue-specific toxicity benchmarks
3. Evaluation of the toxicity of forage contaminated by smelter emissions to horses

For fish and other aquatic organisms, the principal line of evidence used was comparison of measured concentrations of COPECs in surface water with hardness-adjusted national AWQC. This quantitative evaluation was supplemented with qualitative evaluation of results of site-specific toxicity tests and field surveys conducted in the basin.

For amphibians, the following three lines of evidence were used:

1. Comparison of concentrations of COPECs in filtered surface water with literature-derived toxicity benchmarks for embryolarval effects

2. Field-derived estimates of the influence of metal-enriched sediments on amphibian hatching success
3. Field surveys of amphibian species assemblages and relative abundance in wetlands of the lower Coeur d'Alene River basin and Lake Coeur d'Alene

For terrestrial plants, the following three lines of evidence were used:

1. Comparisons of concentrations of COPECs in soil and sediment with site-specific and literature-derived toxicity benchmarks
2. Site-specific phytotoxicity tests
3. Field surveys of plant communities in the Coeur d'Alene River basin

For terrestrial invertebrates and soil processes, the only lines of evidence used were comparisons of concentrations of COPECs in soil and sediment with literature-derived toxicity benchmarks.

This section of the committee's report evaluates the ERA with respect to whether all the available lines of evidence were considered, whether the weight-of-evidence evaluation for each receptor was appropriate, and whether all significant uncertainties were identified and discussed.

Aquatic Receptors

The risk characterization for aquatic life includes a discussion of the ameliorating effects of hardness on metal bioavailability. The ERA did not use current models, such as the biotic ligand model (Santore et al. 2001, 2002), to quantify the influence of organic and inorganic ligands on metal toxicity (see Box 7-2); however, this model may not have been sufficiently developed at the time the ERA was performed.

BOX 7-2 The Biotic Ligand Model

In the biotic ligand model (Di Toro et al. 2001), the site of toxicity is treated as a ligand (a biotic ligand) capable of reacting with the toxic metal. Other chemical species, such as protons and calcium ions, compete with the toxic metal for the reaction sites on the biotic ligand. The toxic metal can react with organic and inorganic ligands in the water, and these too will react with other chemical species, such as protons and calcium ions in the water. A computer equilibrium model is used to compute the concentrations of all chemical species in the system. Toxicity is predicted based on the accumulation of the toxic metal by the biotic ligand. Equal toxicity occurs in waters of different chemical composition when the predicted accumulation of metal is the same, regardless of differences in the total concentration of the metal in the water.

Risk characterization for metals in the Coeur d'Alene River is complicated because of habitat modifications such as channelization and dredging that can also negatively affect aquatic biota. This has resulted in habitats that are nonoptimal for trout, one of the key aquatic receptors. However, given the sensitivity of salmonids and certain benthic taxa (Ephemeroptera, Plecoptera, and Trichoptera) to metals, the emphasis on metal exceedances is warranted. The current structure of the risk characterization emphasizes that toxicity determinations using a "single-metal by single-metal" testing approach may not be appropriate. However, several site-specific ambient media toxicity tests (toxicity tests using water or sediment from the basin) were summarized for fish and macroinvertebrates and are included in the analysis. These types of assays, to the extent that the exposures represent unadulterated environmental media, necessarily account for the range of metals in the environment and other confounding factors such as bioavailability. For instance, Woodward and colleagues have shown that the combination of metals in the river water does influence trout growth and behavior (Woodward et al. 1997). Additional support is provided by population assessments that show substantially decreased populations of fish in the highly contaminated reach of the South Fork downstream from the confluence with Canyon and Ninemile Creeks (ERA, Appendix E).

In situations like the Coeur d'Alene River, where multiple influences and multiple stressors exist, the benthos can be a good overall indicator of habitat quality (La Point et al. 1984; Kiffney and Clements 1993; Griffith et al. 2004). Characterization of effects of metal contamination in the Coeur d'Alene River was too limited to support strong conclusions. Ambient media toxicity tests (ERA, Appendix E, pp. E-61 to E-62) appeared to show that the benthic invertebrates present in contaminated reaches of the river are relatively stress-tolerant. However, only very limited comparisons between benthic communities in contaminated versus reference stream reaches were possible because the surveys conducted in different areas utilized inconsistent sampling techniques.

Potential receptors in the sediments of Lake Coeur d'Alene receive very little attention in the ERA, although ample evidence exists about the extent and magnitude of sediment contamination in Lake Coeur d'Alene (Funk et al. 1975; Horowitz et al. 1993, 1995). Because the lake can serve as a conduit for metals loading to the downstream Spokane River, it is important to develop a better understanding of the role of lake benthos in metal movement. In the ERA, there was ample evidence that, at least at certain times, sufficient metals exist downstream of the lake to affect trout.

The risk characterization failed, however, to treat the river as a continuum (see discussion in Chapter 3 of this report), in which fish life history, competition, and predator behavior within the Coeur d'Alene River system is integrated with habitat and pollutant components. The individual segments of the river are treated as unique and defined, with little appreciation for the connectedness of the upper reaches, the lake, and consequences downstream in the Spokane River. There is little regard to the dependence of downstream biota on upstream events and activities. Yet, fish movement up- and downstream were noted in several reports. Fish use different habitats in different life history stages and need certain habitats at particular times.

Terrestrial Receptors

Risks to terrestrial receptors were adequately characterized where appropriate exposure and effects data were available to conduct a risk assessment. In the case of waterfowl, particularly swans, risks were appropriately characterized, integrating exposure assessment in the field, exposure modeling validated by laboratory studies, and effects assessment that included field collations and laboratory studies of lead toxicosis in waterfowl ingesting Coeur d'Alene River basin sediment.

In the case of waterfowl, all lines of evidence were considered and the weight of evidence clearly demonstrates the following:

1. Lead introduced into the Coeur d'Alene River basin from mining activities had accumulated in the environments occupied by waterfowl.
2. In those contaminated environments, waterfowl receptors are being exposed to high concentrations of lead, as validated by in vivo assessment of exposure levels.
3. Effects are occurring that include both mortality and morbidity of waterfowl in the field, as demonstrated by laboratory studies with several waterfowl species.

For other terrestrial receptors, data are adequate to demonstrate potential risks but not to document the presence of risks to the high degree of certainty that was possible for waterfowl. In the case of songbirds, for instance, inadequate data are provided to fully assess risks present in the Coeur d'Alene River basin. Lead exposures to songbirds in the Coeur d'Alene River basin were reported by Johnson et al. (1999). Livers and blood from song sparrows and American robins were collected from seven sites. Although lead concentrations found in livers of song sparrows in the assessment area were significantly greater than those in the reference sites, effects of these differences were not examined. Sediments collected from Killarney Lake were used in a 3-week feeding trial to test the bioavailability of lead from contaminated sediment in northern bobwhites (C*olinus virginianus*). No overt indications of lead poisoning were observed, and no differences in body weights were detected (Connor et al. 1994). Accumulation of lead was observed in the tissues below levels indicative of clinical lead poisoning and below the "background levels" recorded in wild populations.

Substantially fewer data were available for non-avian terrestrial receptors. This limitation was recognized by EPA in the ERA, which stated that "with the exception of receptors for which no risks were identified, the strength of risk conclusions as determined by the abundance, quality and concurrence of available lines of evidence was generally low for most mammalian receptors. This is because few lines of evidence were available for most mammals, and when multiple lines of evidence were available, there was generally little concurrence" (CH2M-Hill and URS Corp. 2001, p. 5-2).

Thus, for all terrestrial receptors other than waterfowl, there is very high uncertainty concerning the magnitude and spatial extent of risks due to lead and other metals released into the environment of the Coeur d'Alene River basin. It should be possible to address this shortcoming if additional data are collected through the Basin Environmental Monitoring Plan (URS Group. Inc. and CH2M Hill 2004).

Therefore, because of the strength of the waterfowl data and the well-established causal relationship between lead-contaminated sediment and waterfowl mortality, models predicting waterfowl risk based on sediment concentrations are appropriate to develop cleanup levels. The model use is further supported by other information including laboratory and field evidence on the response of swans to lead, and their feeding ecology, that make them highly prone to be exposed through sediment ingestion. Existing data are insufficient to develop comparable models for other wildlife receptors.

VALIDITY OF CONCLUSIONS

Aquatic Receptors

The risk assessment for aquatic receptors was largely limited to salmonids and benthic invertebrates present in the South Fork of the Coeur d'Alene River and its tributaries. Risks due to aqueous and dietary uptake of metals (particularly zinc and cadmium) were adequately characterized for the individual segments of the Coeur d'Alene River, and conclusions about these risks appear to be valid. For trout and sculpin, particularly in the upper basin, risk conclusions were based on toxicity tests that integrated in-stream exposure assessments, modeling effects validated by laboratory toxicity studies, and several behavioral effects studies (both in-stream and laboratory). For other fish and for amphibians, far fewer data were collected in field and laboratory analyses. Conclusions about these receptors are more uncertain.

Contributions to observed aquatic community degradation from habitat degradation unconnected to metal exposures, however, were not fully characterized. Fish respond sensitively to modifications of the physical habitat (for example, substrate size, flow velocities, and depth). Events upstream (mitigation, dredging) could influence downstream habitat quality; moreover, fish communities occupying an impaired habitat may not recover as expected when metal concentrations are reduced.

Terrestrial Receptors

Conclusions about risks to individual waterfowl exposed to particulate lead in wetland sediments are well supported by multiple lines of evidence. Conclusions about risks to other types of terrestrial receptors are much less certain.

The evidence for defining population- or community-level risk to terrestrial receptors is limited. Even in the case of waterfowl, it is not clear whether populations are being impaired by exposure to lead and other metals. Although EPA guidance permits risk assessments for migratory waterfowl and other special status species to be based on individual-level rather than population-level risks, the question of whether populations are being impaired is still relevant to selecting remedies and monitoring ecologic recovery within the Coeur d'Alene River basin. At present, any conclusions about population- or community-level risks must be regarded as highly uncertain.

Habitat-related stressors to wildlife are discussed only nominally in the ERA. However, in the Coeur d'Alene River basin, these stressors are of limited importance to assessment of wildlife toxicology. Moreover, habitat, particularly for waterfowl in the lower basin, is not a limiting factor.

USE OF THE ERA IN RISK MANAGEMENT

EPA's guidance for Superfund ERAs (EPA 1997) states that the risk-description component of an ERA should include, for each chemical and environmental medium considered, a range of concentrations that bound the threshold for estimated adverse ecologic effects, given the uncertainty inherent in the data and models used. The lower bound of this range should be based on conservative assumptions and NOAELs. It should be unlikely that adverse effects due to chemical exposure would occur if concentrations were reduced to this level. The upper bound of this range should be based on observed impacts or predictions that ecologic impacts could occur if this bound were exceeded. The purpose of these ranges of values is to provide risk managers with a range of target levels for selecting a preferred remedy.

In the ERA for the Coeur d'Alene River basin, these values are termed PRGs. Because the PRGs are an important output from the risk assessment, no evaluation of decision-making processes for the Coeur d'Alene River basin would be complete without an evaluation of the validity of the PRGs and the use made of the PRGs in remedy selection.

Validity of PRGs

Section 5.2 of the ERA documents PRGs for the Coeur d'Alene River basin. PRGs were developed for soil, sediment, surface water, and physical/biological habitat characteristics. The most complex set of PRGs was developed for terrestrial wildlife exposed to contaminated soil and sediment. For each of these two media and for every contaminant of concern, a range of values was provided that reflected NOAEL-based TRVs, LOAEL-based TRVs, and ED_{20} (20% effective dose) values. For each of these three PRG types, EPA used its exposure models to back-calculate soil and sediment concentrations that would produce an exposure estimate equal to the appropriate TRV or ED_{20}. The back-calculation was performed for each avian and mammalian receptor species, yielding a distribution of values for potential PRGs. The 10th percentile of this range was selected as the PRG. For soil biota (plants, invertebrates, and microbial processes combined), a separate PRG for soil-dwelling organisms was also developed from literature-derived toxicity data. The PRGs for these biota were calculated by examining the distribution of LOAELs for each chemical of concern extracted from two widely-used summaries of soil toxicity studies (Efroymson et al. 1997a,b). For each chemical, the 10th percentile of the distribution of toxicity values from the literature was chosen as the PRG. To account for the possibility that the literature-derived PRGs could be lower than regional background levels, 90th percentile soil and sediment background concentrations were also estimated. For cases in which the background concentrations were higher than the toxicity-based PRGs, background was recommended as the PRG used in risk management.

For wildlife exposed to sediment, EPA developed an additional PRG for lead by adapting the exposure/effects model of Beyer et al. (2000) to predict sediment concentrations associated with background levels of lead in the blood and liver of four waterfowl species. The 10th percentile of the resulting distribution of sediment concentrations was chosen as the PRG.

For aquatic biota exposed to contaminated sediment and water, the only PRGs provided were freshwater sediment screening values recommended by National Oceanic and Atmospheric Administration (NOAA), national AWQC, and background concentrations. For surface water, the higher of either background or the hardness-adjusted national ambient criterion was recommended as the PRG for each CSM unit. For sediment, the higher of either background or NOAA's screening value was recommended as the PRG.

The PRGs for terrestrial wildlife are well documented, although based only in part on site-specific data. They appear to be consistent with EPA guidance, although the high reliance on literature-derived TRVs for many species contributes substantial uncertainty to the calculated values. The PRGs for aquatic biota, and especially for sediment, appear more questionable and do not appear to be consistent with EPA guidance. For surface water, the AWQC are potentially applicable or relevant and appropriate requirements (ARARs) and for this reason should be included as PRGs. However, by definition, the criteria are intended to protect at least 95% of exposed aquatic species. As long as the AWQC are not exceeded, no ecologicly significant adverse effects should occur. Exceedance of the criteria, however, does not imply that adverse effects will occur. Figures 3-23 through 3-30 of the ERA compare the AWQCs for cadmium, copper, lead, and zinc with acute and chronic effects concentrations derived from various published sources. In all cases, AWQC fall near or below the lowest published effect value. Hence, although the AWQC provide a lower-bound PRG value as defined in EPA guidance, they may not be suitable as an upper bound. For sediment, the ERA does not provide a rationale for using the NOAA screening values as PRGs. All the values used are "threshold effects levels," which are estimates of the lowest values at which adverse effects might occur. These values might be suitable as lower-bound PRGs, but they clearly are inappropriate as upper-bound PRGs or as the only PRGs recommended for use in risk management.

Use of PRGs in Defining the Proposed Remedy

The ecologic PRGs are reproduced in the ROD (EPA 2002, Tables 7.2-6 to 7.2-9) and characterized as being concentrations that are "protective" of terrestrial and aquatic biota. However, with the exception of the AWQC values, it does not appear that any of these values were actually used in remedy selection. As discussed in Section 8 of the ROD, the AWQC were considered to be potential ARARs and, for this reason, were identified as long-term cleanup benchmarks. Although the ERA developed wildlife PRGs for five chemicals of concern, lead was the only chemical used in defining the remedy for soil/sediment. The value selected as the remediation benchmark, 530 mg/kg, is within the range of PRG values identified in the ERA. This value is the LOAEL from a modeling study that incorporates laboratory and field components (Beyer et al. 2000). This study developed an exposure model that described a lowest-effect level of lead as 530 mg/kg in sediments, a reasonable number based on the science to date (see Box

BOX 7-3 Relating Sediment Lead Concentrations to Waterfowl Effects—Derivation of the Cleanup Criterion in the Lower Basin

EPA heavily relied on one study in particular in decisions relating to the toxicity of metals-contaminated sediments to waterfowl and determination of a remedial goal for the protection of waterfowl.

Beyer et al. (2000) reported on studies of waterfowl experimentally fed sediments from the Coeur d'Alene River basin and compared their results with field studies conducted in the basin to relate sediment lead concentration to injury to waterfowl. The first step in their model development involved the relation of sediment lead concentration to blood concentration in mute swans (*Cygnus olor*), and these data were compared with sediment ingestion estimated from analyses of feces of tundra swans (*Olor columbianus*), migratory residents in the Coeur d'Alene River basin. With additional laboratory studies on Canada geese (*Branta canadensis*) and mallards (*Anas platyrhynchos*) fed sediment contaminated with lead, a general relation of blood lead to injury in waterfowl was developed. By integrating the exposure and injury relations, the no-effect concentration of sediment lead was estimated as 24 mg/kg, and the lowest effect level was estimated as 530 mg/kg (based on reduced δ-aminolevulinic acid dehydratase activities). Beyer et al. then combined their exposure equation with data on blood lead concentrations measured in lead-intoxicated tundra swans in the basin and estimated that some mortality would occur at a sediment lead concentration as low as 1,800 mg/kg.

EPA made a risk management decision to use the site-specific protective value lead concentration of 530 mg/kg as the benchmark cleanup criterion for the soil and sediment in the lower basin for protection of waterfowl. Although the value was not derived from the extensive analyses conducted in the ERA (and reviewed in this report), it does fall within the estimated range of sediment lead concentrations protective of aquatic birds and mammals that was determined in the ERA.

7-3). This value is supported by substantial field evaluation of lead effects on waterfowl in the Coeur d'Alene River basin, as reported by Henny et al. (2000) and in particular a report by Blus et al. (1999), reporting substantial lead toxicity in tundra swans captured in the Coeur d'Alene River basin. However, no specific justification for the use of this value rather than a NOAEL or some other value is provided in the ROD (also see Chapter 8, Ecologic Risks: Rationale for Determining Levels of Remediation). The sediment PRGs do not appear to have been used at all in remedy selection.

For surface waters, rather than relying on the PRGs, remedy selection appears to have been based on a set of "interim fishery benchmarks" (URS Greiner and CH2M Hill 2001c) that were developed outside the ERA process. These benchmarks, which are discussed in greater detail in Chapter 8 of the committee's report, identify interim remediation targets in terms of desired characteristics of the fish community in different stream reaches and metal concentrations expected to support fish communities of the desired types.

No explanation is provided in the ROD concerning why the PRGs played such a small role in the development of the proposed interim remedy. Reliance on a study performed externally to the ERA appears quite remarkable to the committee, given the extraordinary length and degree of detail concerning ecologic risks provided in the ERA report. It seems likely to the committee that a principal reason for the failure of the ROD to make greater use of the ERA in design of the remedy is that the ERA focused almost exclusively on exhaustive documentation of the presence or absence of risks. Documentation of risks due to chemical exposure and estimation of chemical concentrations that would eliminate those risks is, in fact, all that EPA guidance on ERA requires. If the ERA had been designed differently, it could have been a source of performance metrics and restoration goals for use in implementing EPA's proposed adaptive approach to remediation. Failure to provide these types of essential outputs reflects, in the committee's opinion, a failure both of EPA's guidance and of EPA's decision to rely on existing data to complete the ERA.

Importance of Habitat Impairment Relative to Chemical Toxicity

Habitat degradation occurring as a secondary effect of mining activities is discussed both in the ERA and in the ROD. Qualitative PRGs for riparian, riverine, and lacustrine habitat are recommended in the ERA. The PRGs (CH2M-Hill and URS Corp. 2001, Table 5-11) for each habitat type and physical characteristic state that the habitat should be returned either to pre-mining conditions or to a condition similar to conditions found in selected reference areas that are only affected by non-mining related disturbances. These PRGs were listed in the ROD (EPA 2002, Table 7.2-10) but were not used to define remediation benchmarks.

Despite the abundant evidence of harm caused by zinc and other dissolved metals, there is clear evidence that channel alterations also impaired fish populations in the Coeur d'Alene River (Dunham and others 2003; Wesche 2004). Wesche, using his own sampling and literature data, estimates that 40-80% of the habitat in the South Fork is degraded for trout and concludes that it is habitat limitation that precludes a healthy trout fishery in the South Fork. Substantial channel alterations have occurred in the upper South Fork for the purposes of flood control, remediation, and road building. Historically, much of the floodplain of the South Fork of the Coeur d'Alene River was forested, particularly with large cedars. The forested condition would have led to decreased stream temperatures, increased stream bank stability, and increased habitat complexity, conditions that support high-quality fish and macroinvertebrate communities. These types of habitats no longer exist along the South Fork. These alterations are clearly permanent and may well limit the recovery of aquatic communities in the river, even if all applicable AWQC are met. The conflict between the goal of returning the river to pre-mining conditions and the irreversible effects of urbanization are not discussed in either the ERA or the ROD.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion 1

The ERA is generally consistent with EPA guidance concerning the ERA process, however, EPA's decision to rely on existing data limits the value of the ERA for risk management.

All except one of the components (a data analysis plan) of an ecologic risk assessment as discussed in guidance are included in the assessment. Stakeholders were appropriately involved in planning and implementing the assessment and data selection and evaluation procedures prescribed in EPA's data quality objectives guidance were followed. The results of the assessment were appropriately documented and the PRGs that were developed were consistent with the conclusions of the risk assessment. However, during the problem formulation phase of the ERA, EPA and the other stakeholders chose to bypass the development of an analysis plan and to rely on existing data to complete the ERA. If an analysis plan had been developed, some of the significant data gaps noted in this review could have been filled, and the utility of the ERA for risk management could have been substantially improved.

Conclusion 2

The ERA is generally consistent with best scientific practice in ERA. In some respects (for instance, the selection of representative species and development of literature-derived TRVs) it was more extensive and detailed than are many ERAs. However, there were some potentially significant exceptions that limit the adequacy of the ERA for supporting appropriate remedial actions.

- Assessments for birds (except waterfowl) and mammals were limited to comparisons between modeled dose estimates and literature-derived effects benchmarks. These methods are highly uncertain (although they are widely used in risk assessments).
- The evaluation of benthic invertebrates in the risk assessment included only limited measures of community structure and site-specific toxicity tests. An integrated laboratory and field study designed specifically to

support the ERA could have provided a much stronger foundation for risk management decision making.

• The risk assessment for Lake Coeur d'Alene is not supported by any defined, quantitative study linking metal concentrations in sediments or in the overlying waters to biotic communities despite ample evidence of the presence of elevated metal concentrations. The lack of data precludes an assessment.

Conclusion 3

Support for the ERA's conclusions is strongest with respect to waterfowl (lead) and fish (zinc and other dissolved metals); support for conclusions about other receptors is much more uncertain.

• The waterfowl and fish assessments are supported by multiple lines of evidence, including site-specific data that reflect effects of multiple contaminants. The conclusions concerning risk to waterfowl are especially strong because of the wealth of data on dose-response relationships developed by USGS and the U.S. Fish and Wildlife Service. Conclusions about risks to fish are also well supported, although some uncertainty exists with respect to chemical-specific values because fish within the basin are exposed to multiple chemicals.

• Conclusions about risks to other receptors are uncertain because of reliance on models and literature-derived toxicity data for single-chemical exposures.

Conclusion 4

The level of support for PRGs is highly variable among receptors.

• The range of PRGs for waterfowl is very strongly supported.

• The PRGs for fish, benthic invertebrates, small mammals, plants, amphibians, and birds other than waterfowl are uncertain, and their value for guiding remediation decisions is questionable. All these are based on regulatory criteria, literature-derived TRVs (many of which are highly conservative), and background concentrations rather than site-specific toxicity data. For fish and benthic invertebrates, only lower-bound PRGs are provided.

Conclusion 5

Despite the large number of ecologic studies performed in the basin and the complexity of the analyses provided in the ERA report, the results of the ERA had only a minimal apparent influence on the ROD.

Of the many PRGs developed in the ERA, only the national AWQC were adopted as remediation goals in the ROD. Only one remediation goal, the soil/sediment goal for lead, was based on site-specific data. Instead of basing the interim remediation goal for dissolved metals on the ERA results, the ROD relied on a set of "interim fishery benchmarks" that were developed outside the ERA process.

Recommendation 1

Further research is needed to support remedial actions intended to promote recovery of aquatic and terrestrial biota within the basin. Information is particularly lacking on effects to benthic invertebrate and fish communities in the lower basin, the magnitude and spatial extent of risks to riparian and upland communities, and the condition of benthic communities in Lake Coeur d'Alene in relation to contaminated sediments.

Recommendation 2

Further research is needed on the influence of transport and transformation processes on the fluxes and bioavailability of particulate lead and dissolved metals. Improved understanding of these processes is needed to ensure the effectiveness of remedial actions intended to reduce risks to wildlife and aquatic biota.

Recommendation 3

ERAs at large, complex sites like the Coeur d'Alene River basin should be designed to support remedy selection and not simply to document the presence or absence of risks. In particular, the ERA should be a source of performance metrics and restoration goals for use in adaptive restoration of the basin. EPA's guidance on Superfund ERAs should be modified to encourage the development of performance goals and metrics as part of ERAs for large, complex sites such as the Coeur d'Alene River basin.

Recommendation 4

In developing performance metrics and restoration goals, additional consideration should be given to development-related habitat modifications (for example, stream channelization) that may prevent a return to premining conditions. Remedial activities designed to reduce metals exposure and transport should, to the extent practicable, concomitantly strive to improve habitat for fish and wildlife.

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